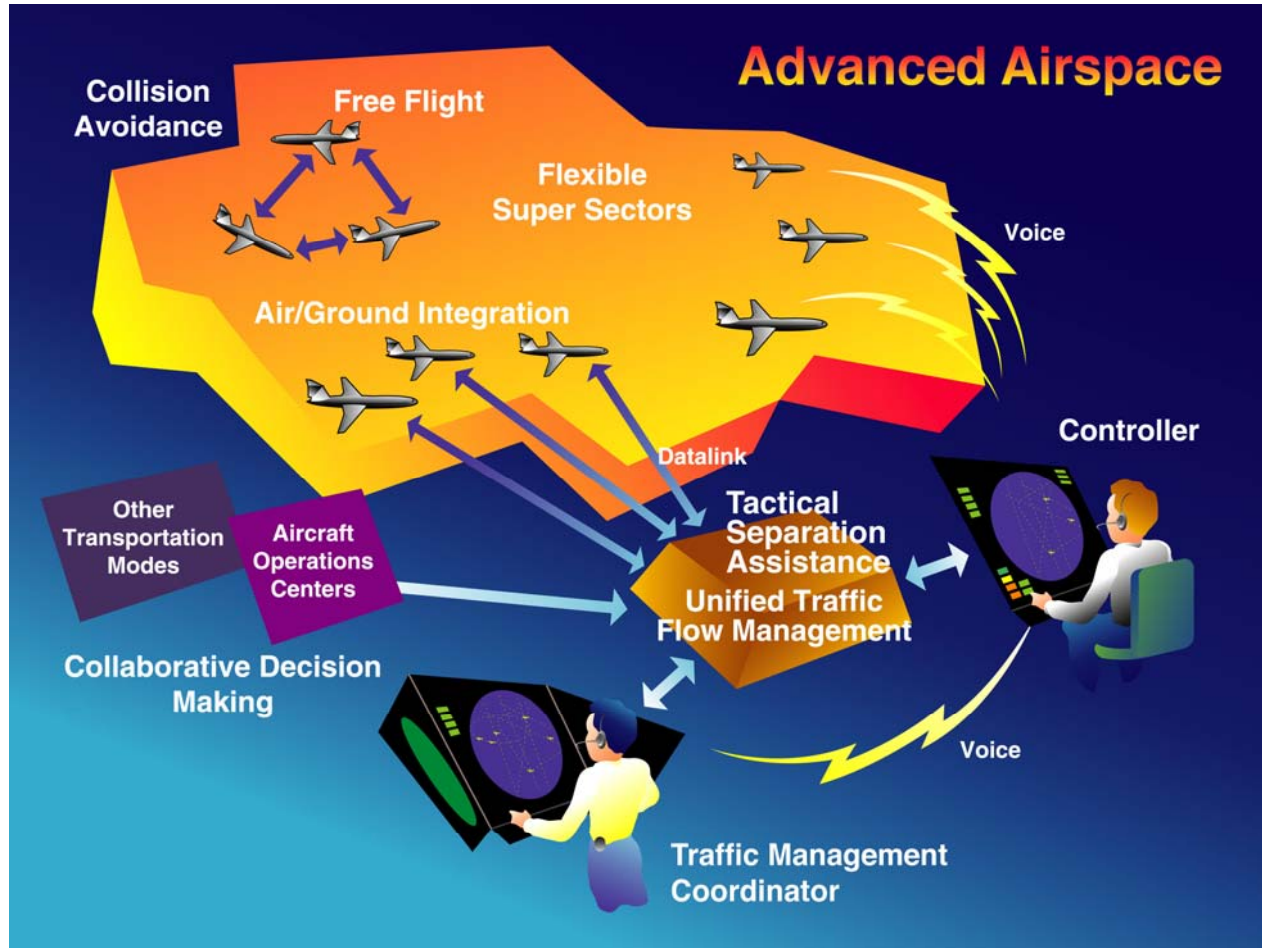


Transforming the NAS: The Advanced Airspace Concept



Presented at VAMS TIM #5

With contributions by

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Goals for Transforming the NAS

Substantially increase capacity, safety, efficiency and transportation security by

- Introducing advanced automation and communication technologies
- Transforming the roles of controllers and pilots

Performance Targets for AAC

- Capacity and Throughput
 - Factor-of-three increase in en route airspace capacity
 - Potential for 25% increase in landing rate
 - Increased utilization of secondary airports
- Efficiency
 - 15% increase in efficiency of aircraft operations en route
- Safety
 - 90% reductions in operational errors
 - Increased aviation security
- Environment
 - Significant noise reductions in the terminal area
- Affordability
 - On board equipment costs comparable to CPDLC installation
 - Ground system costs comparable to ERAM software development
 - Reduced cost of air traffic services

Summary of AAC

- An architecture that provides for a stepwise transition toward automating key functions performed on the ground
- Data link (CPDLC) is the key enabler of AAC operations
- In its mature state, separation assurance is automated, and interactions between systems on the ground and equipped aircraft are performed autonomously, through data link communications
- Pilots of equipped aircraft have the ability to replan trajectories on demand by interactions with automated trajectory server on the ground
- 4D trajectories are the basis of agreed transactions between ground system and aircraft and are conflict free for a period of time

Summary of AAC (continued)

- System architecture is fault tolerant and can be designed not to exceed a specified collision risk
- Fault tolerance design does not depend on controllers immediately having to take over responsibilities for separation assurance at high traffic densities during a system wide failure event
- Controller's role is to handle special situations, impose flow restrictions, reroute traffic flows during weather, respond to pilot requests, handle selected aircraft manually, etc.
- Airspace consists of supersectors which are substantially larger than conventional sectors.

Summary of AAC (concluded)

- Cost and complexity of airborne components required for operation in advanced airspace are kept to a minimum.
- Essential ATC functions are automated primarily within the ground system to minimize cost and risk
- Safety certification will be required for those ground-based subsystems and associated aircraft systems that provide tactical (short time) separation assurance
- Cockpit traffic displays based on ADS-B could be developed for separation assurance as part of the safety net used during system faults and for other applications as appropriate

Comparing Operations in Today's System with AAC

Today's System

Controllers are responsible for separation of all aircraft

Controllers issue clearances manually



Aircraft in sector

- 1.
- 2.
- ...
- 7.
- ...
- 15.

Channel capacity: 6 clearances per minute delivered serially in priority order

Efficiency related services unavailable during periods of high workload

Capacity and airspace access constrained due to workload bottlenecks

AAC

A/C request/receive clearances automatically via data link

AAC Ground System



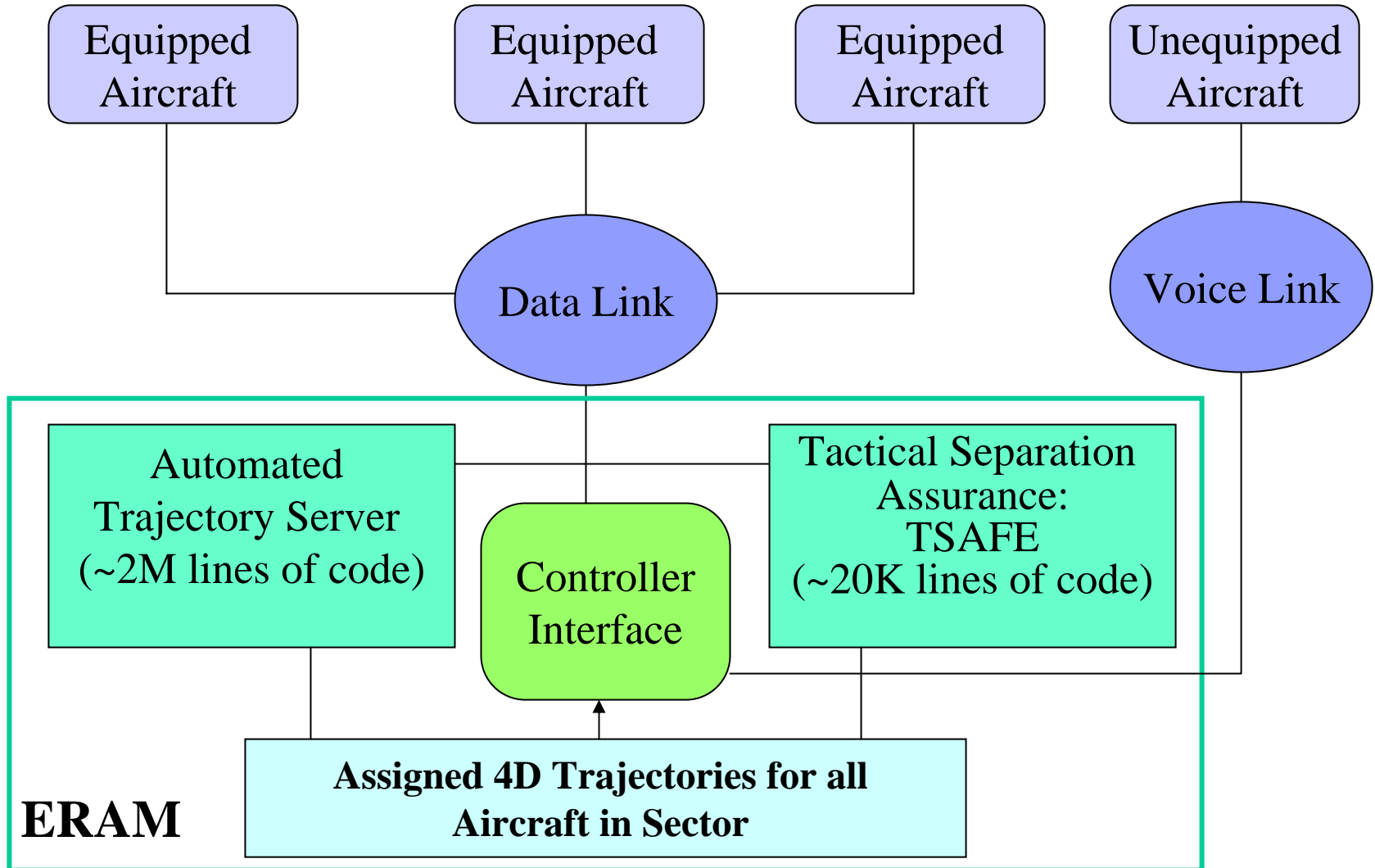
- 1. Aircraft in sector
- 2.
- ...
- 7.
- ...
- 15.
- ...
- 27.
- 28.
- ...
- ...
- ...
- 44.
- 45.

Trajectory uplinked when required for separation assurance

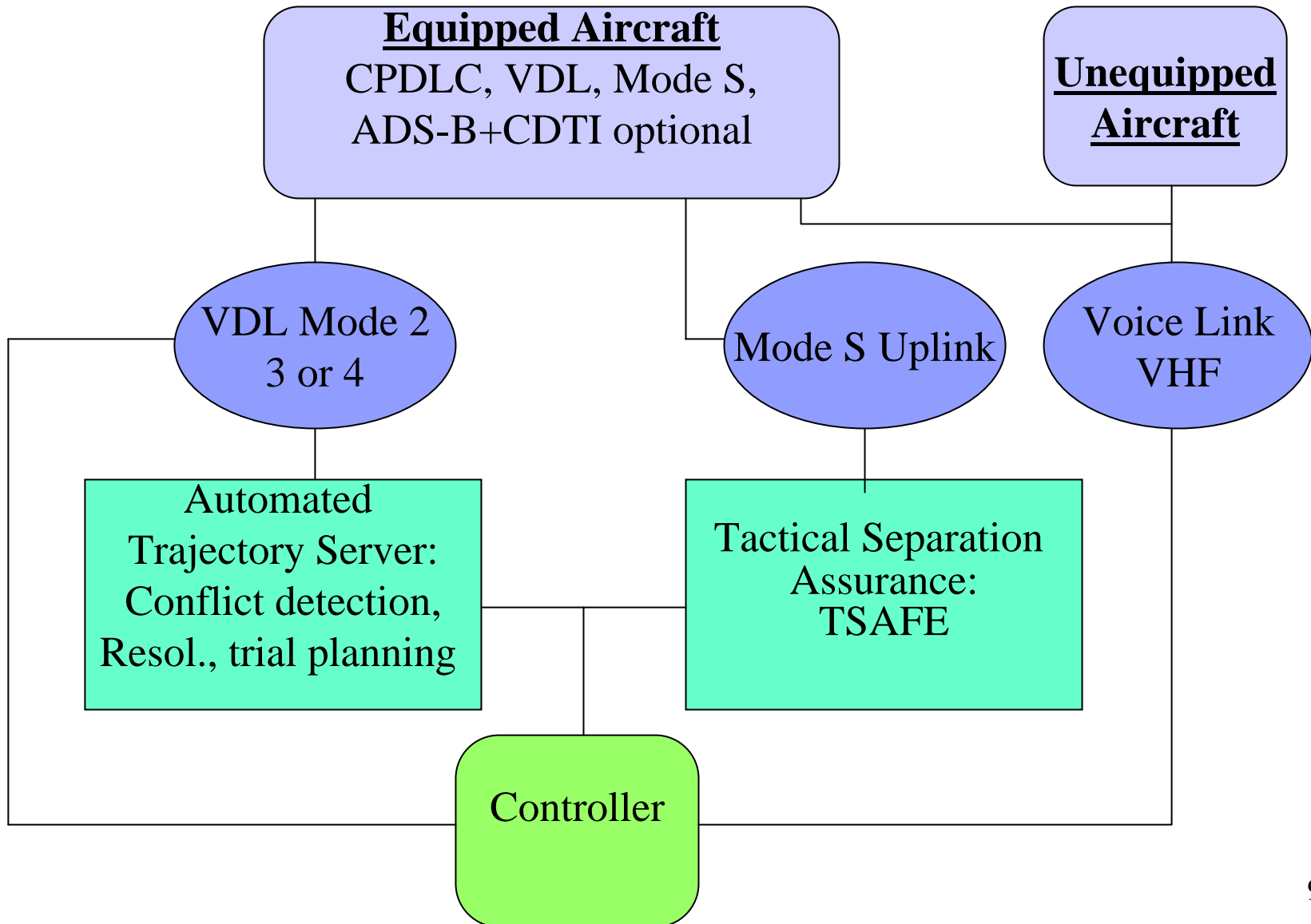
Channel capacity: 60 trajectories per minute delivered concurrently

Controller communicates with aircraft requiring special services

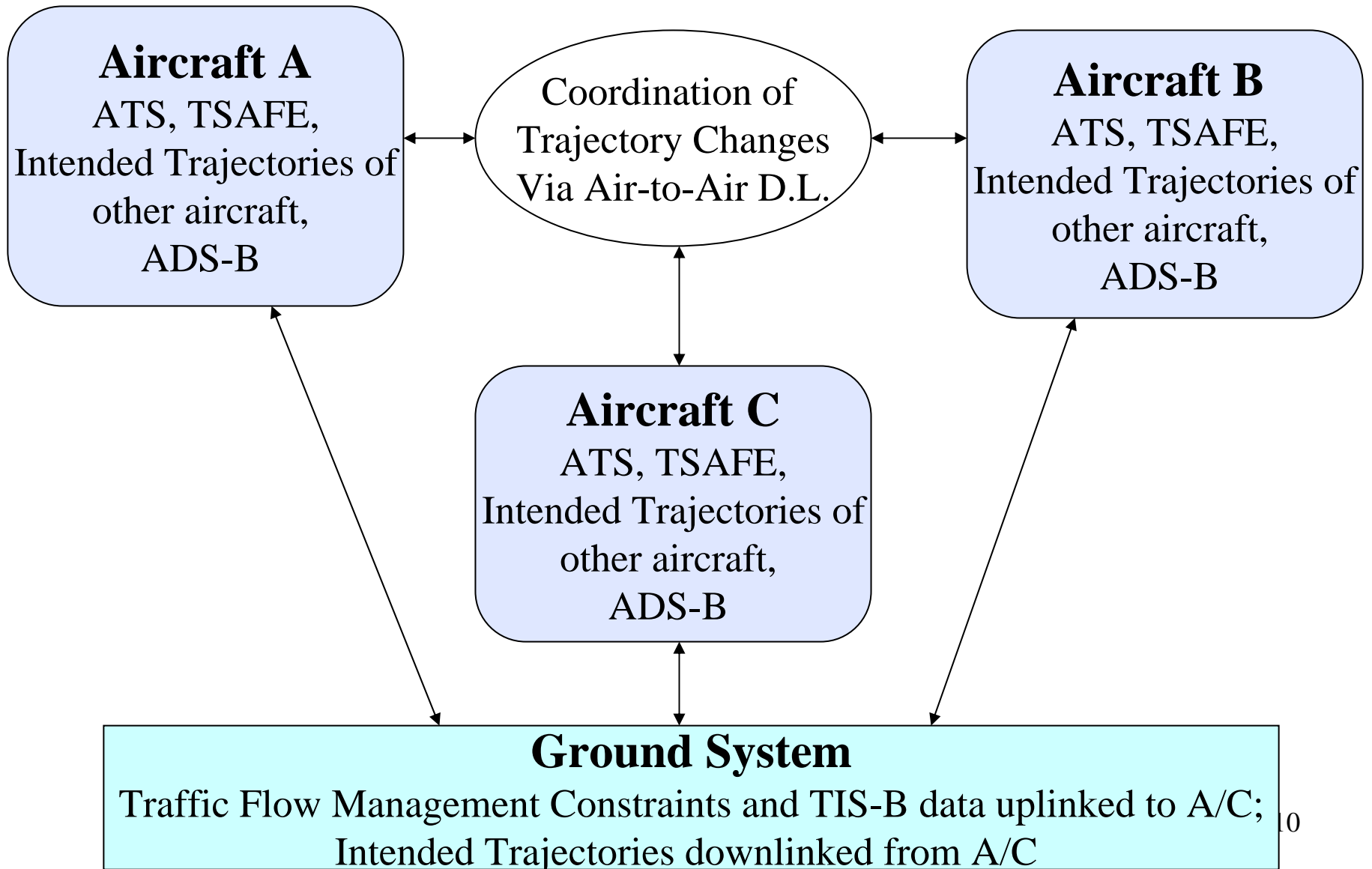
System Architecture



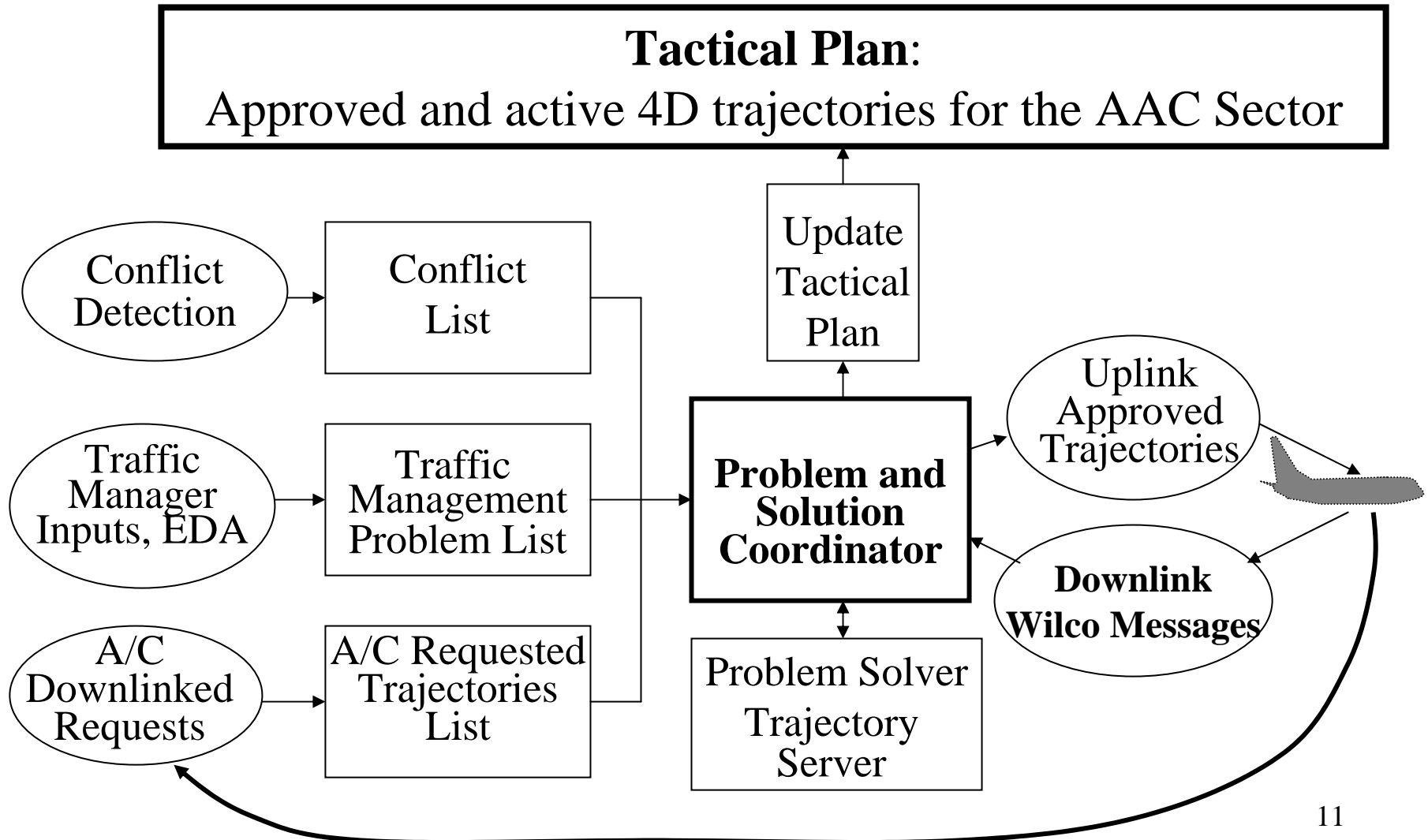
Communication Architecture



System Architecture for Autonomous Airborne Separation Assurance

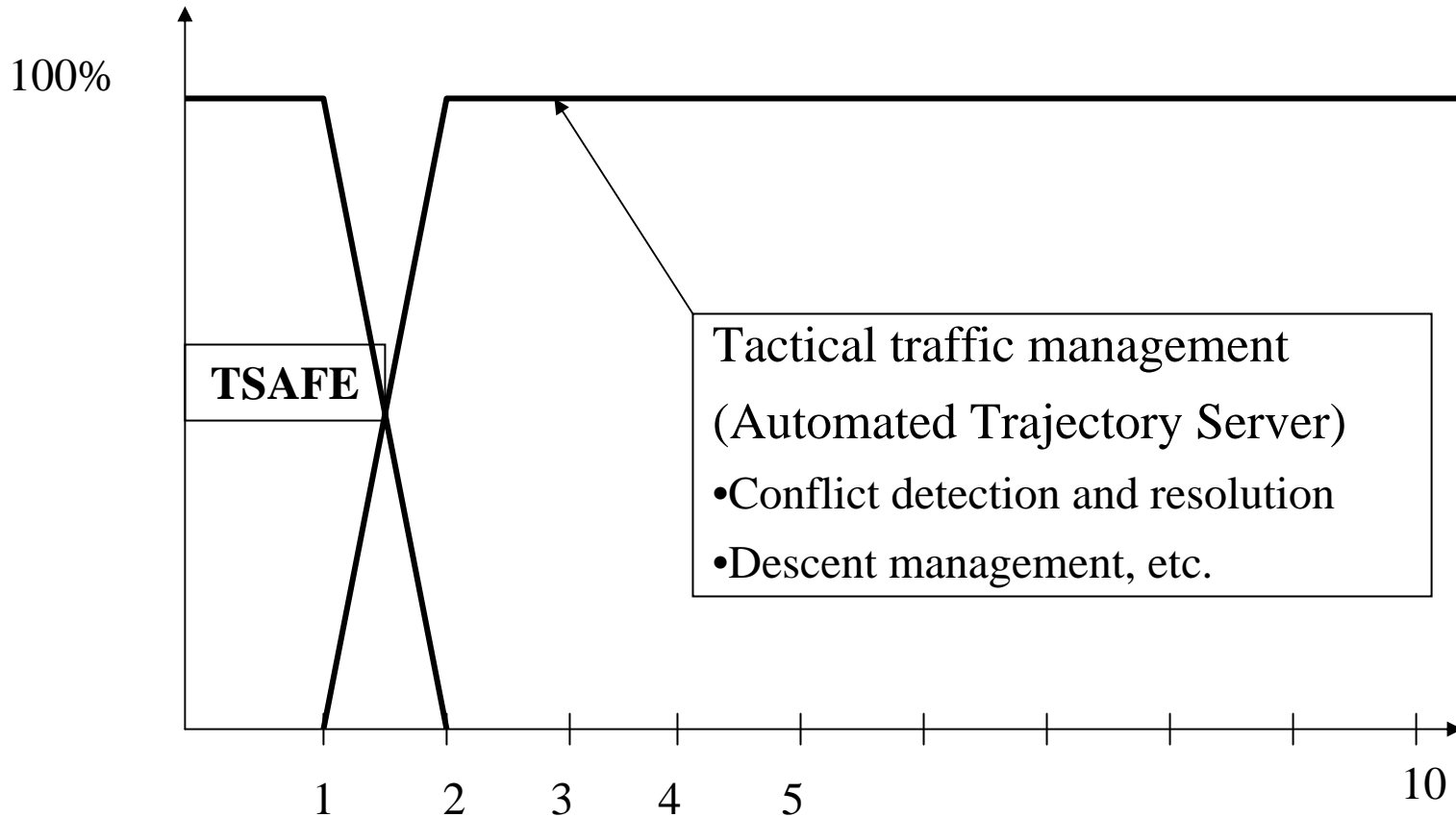


Trajectory Change Management



Phases of Control

Control Authority



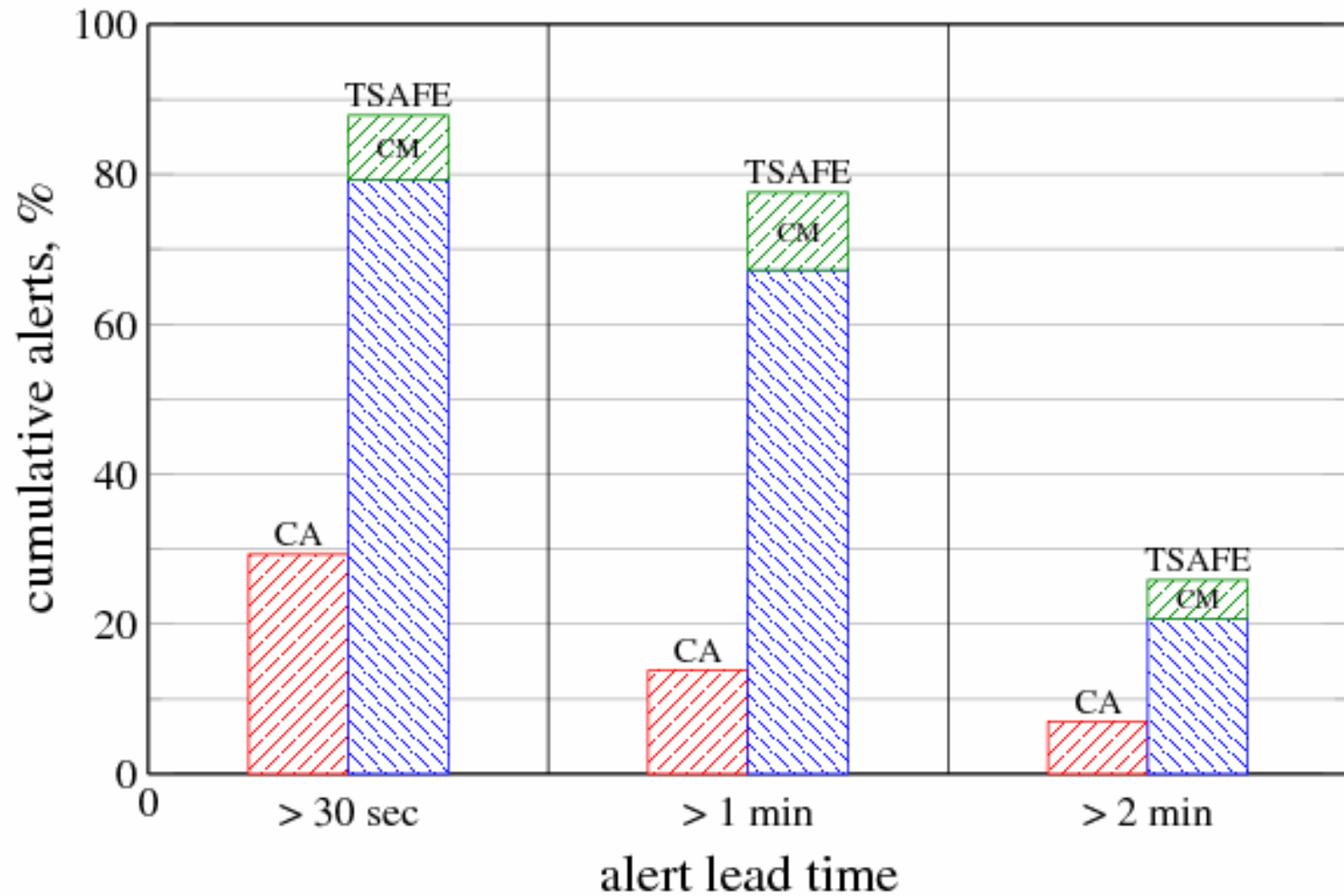
Time to loss of separation, minutes from current time

TSAFE: TACTICAL SEPARATION ASSISTED FLIGHT ENVIRONMENT

- TSAFE is a key safety-critical backup component of AAC on the ground that will detect imminent conflicts and generate resolution advisories
- The detection part of TSAFE applies to the current ATM system as an improvement to Conflict Alert
 - Has been implemented in CTAS; runs with live input data
- Replay of operational error cases shows that TSAFE provides alerts more consistently than Conflict Alert
- FAA and NASA are investigating the feasibility of incorporating selected TSAFE-Alert functions into Conflict Alert
 - TSAFE-Alert has been transferred to the NextNAS program as a near term development effort for the current system

TSAFE vs. CA Cumulative Alert Lead Times

58 operational error cases

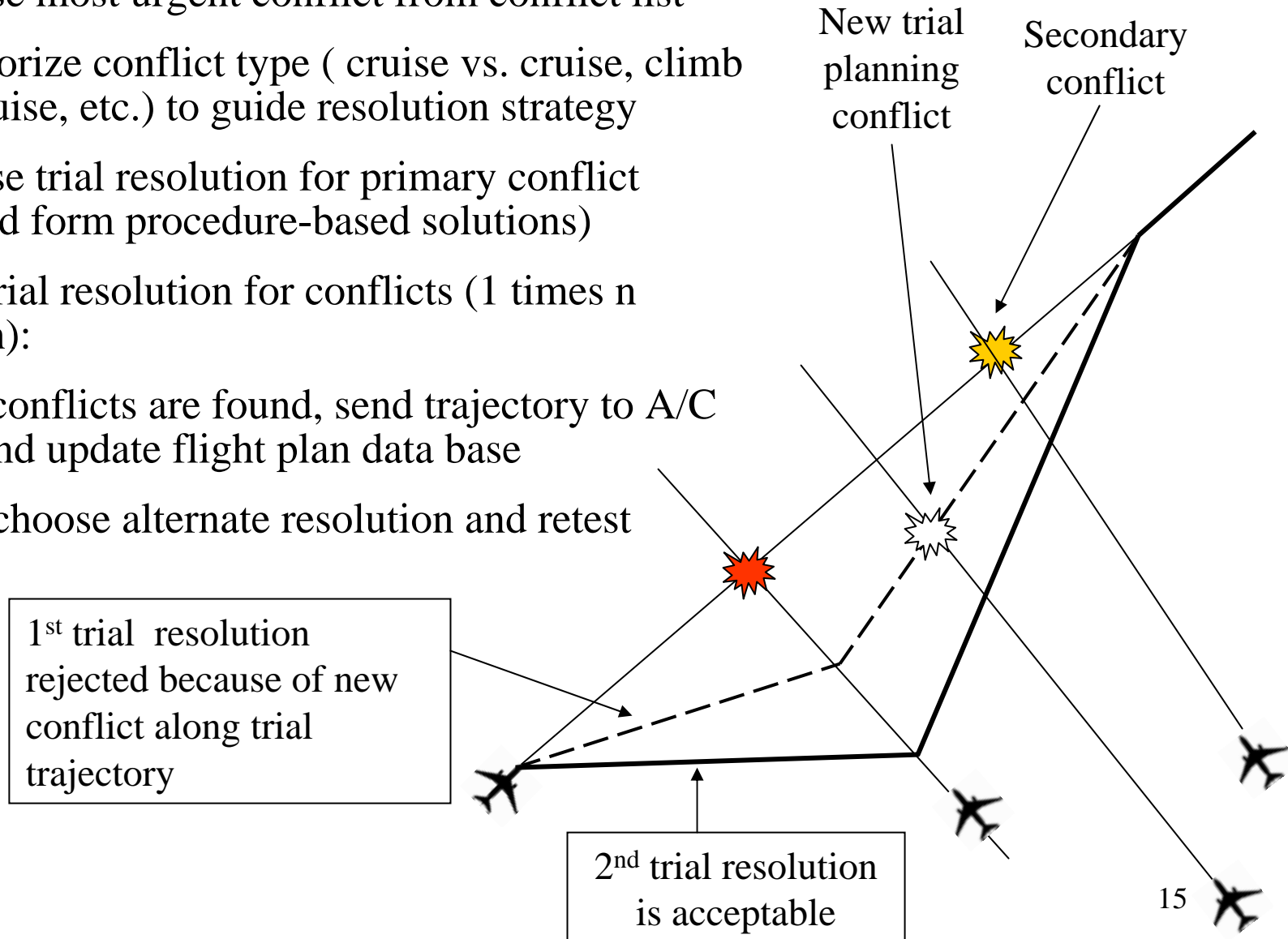


Automated Trajectory Server-Resolution Generator

1. Choose most urgent conflict from conflict list
2. Categorize conflict type (cruise vs. cruise, climb vs. cruise, etc.) to guide resolution strategy
3. Choose trial resolution for primary conflict (closed form procedure-based solutions)
4. Test trial resolution for conflicts (1 times n search):

If no conflicts are found, send trajectory to A/C and update flight plan data base

Else, choose alternate resolution and retest

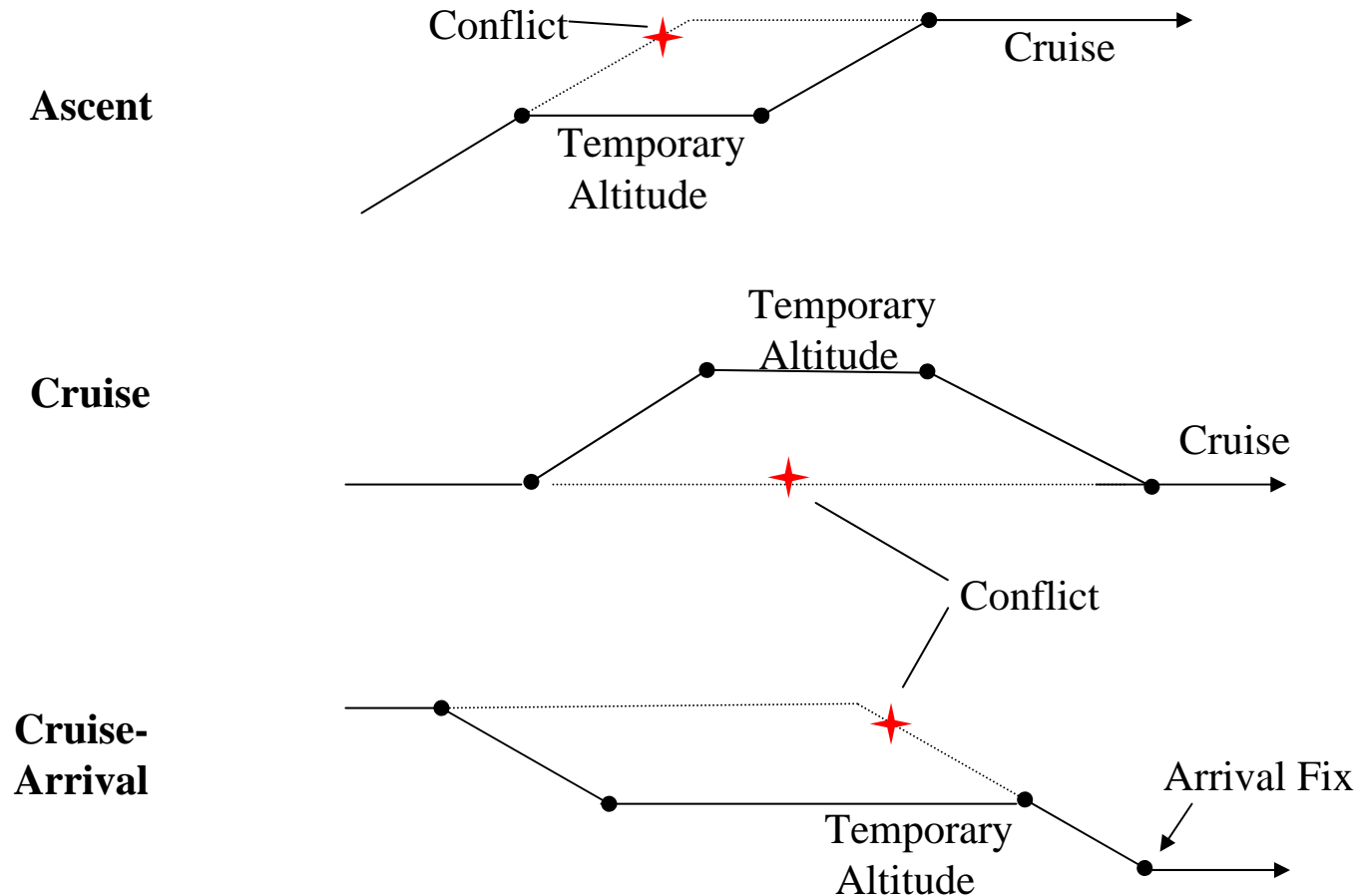


Vertical Resolution Procedures

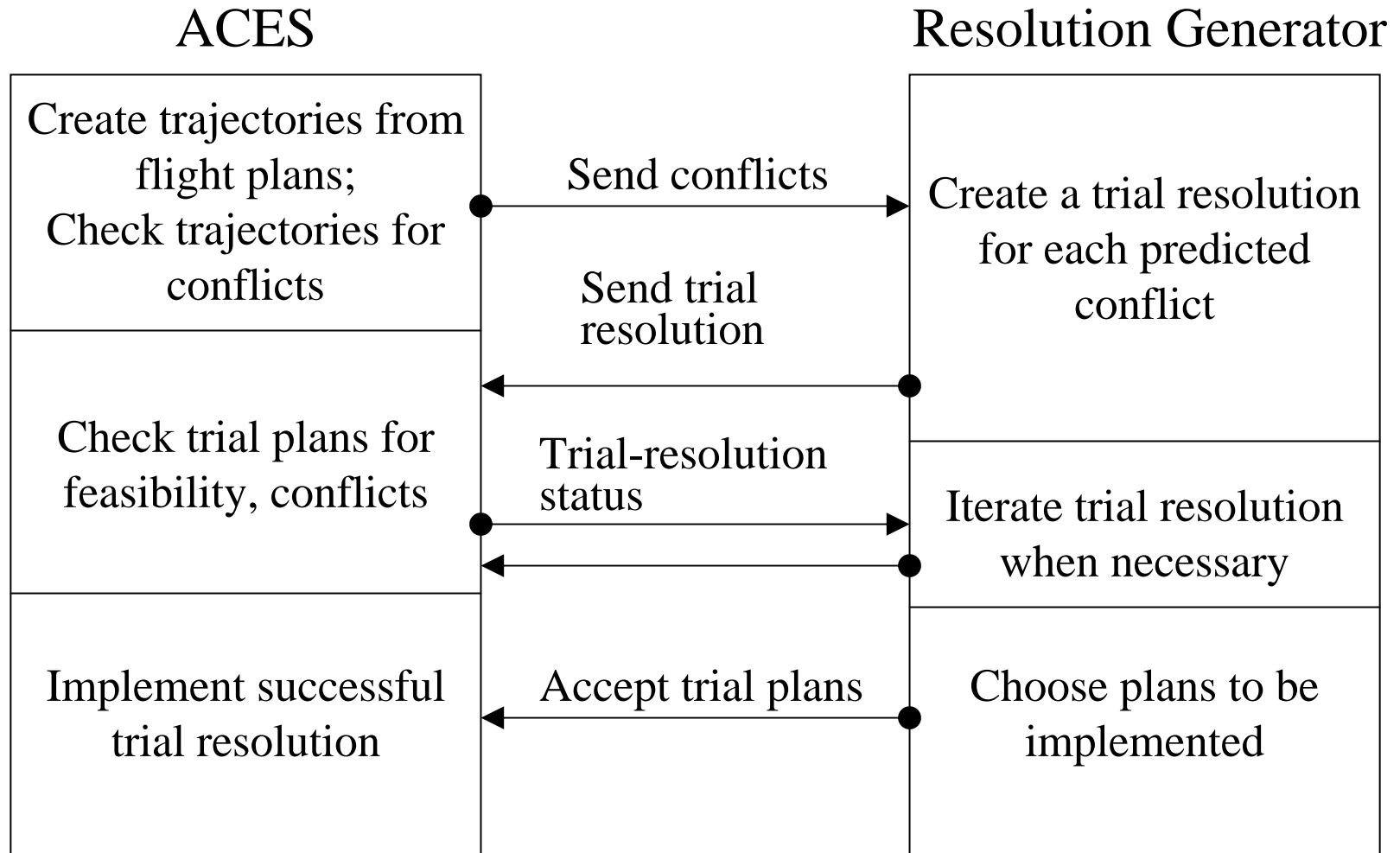
Resolution procedures and trajectories are designed to be compatible with established controller procedures and flight plans

Initial state of
resolution A/C

Resolution Procedures

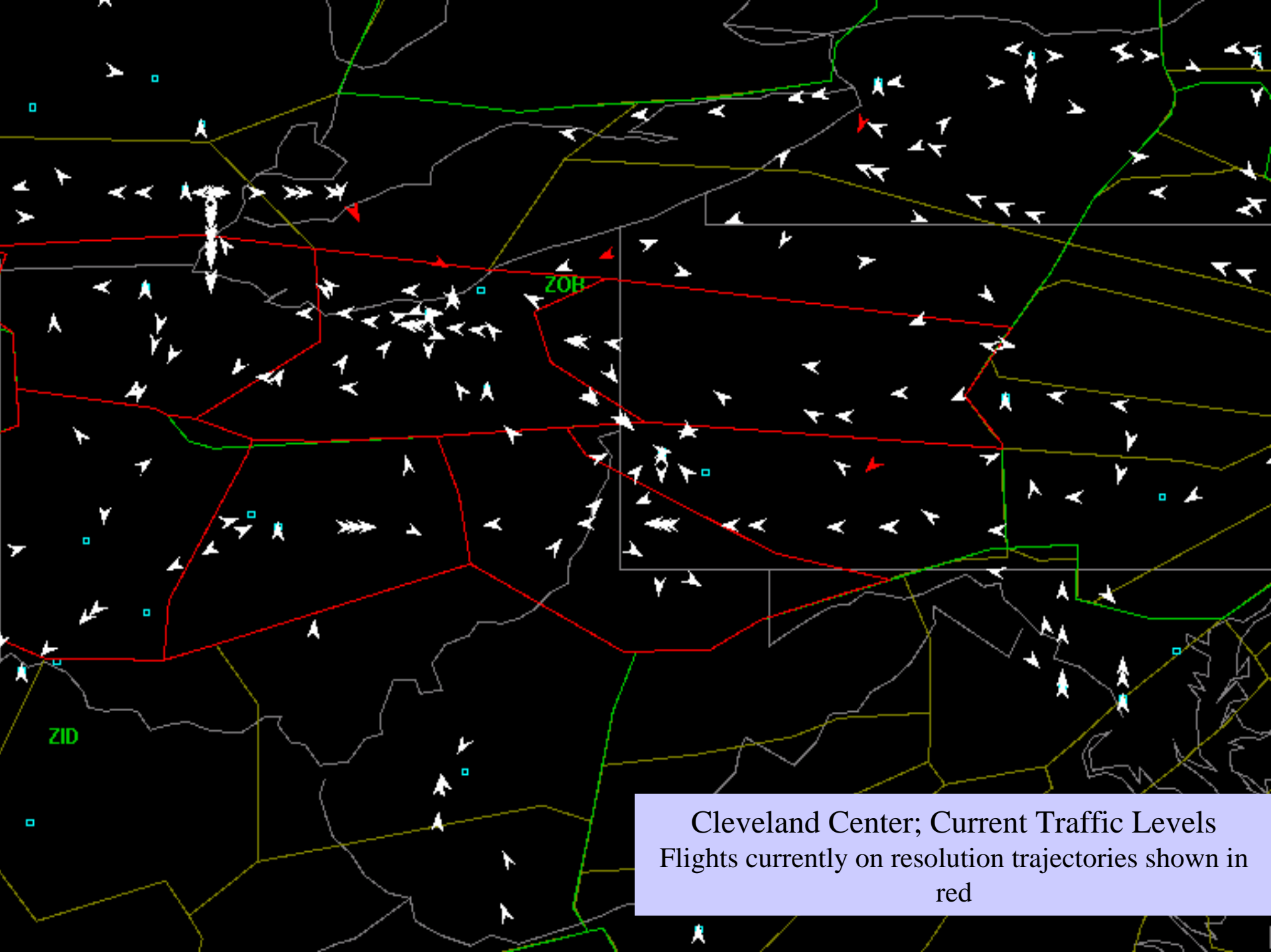


Interface of ACES and AAC Resolution Generator

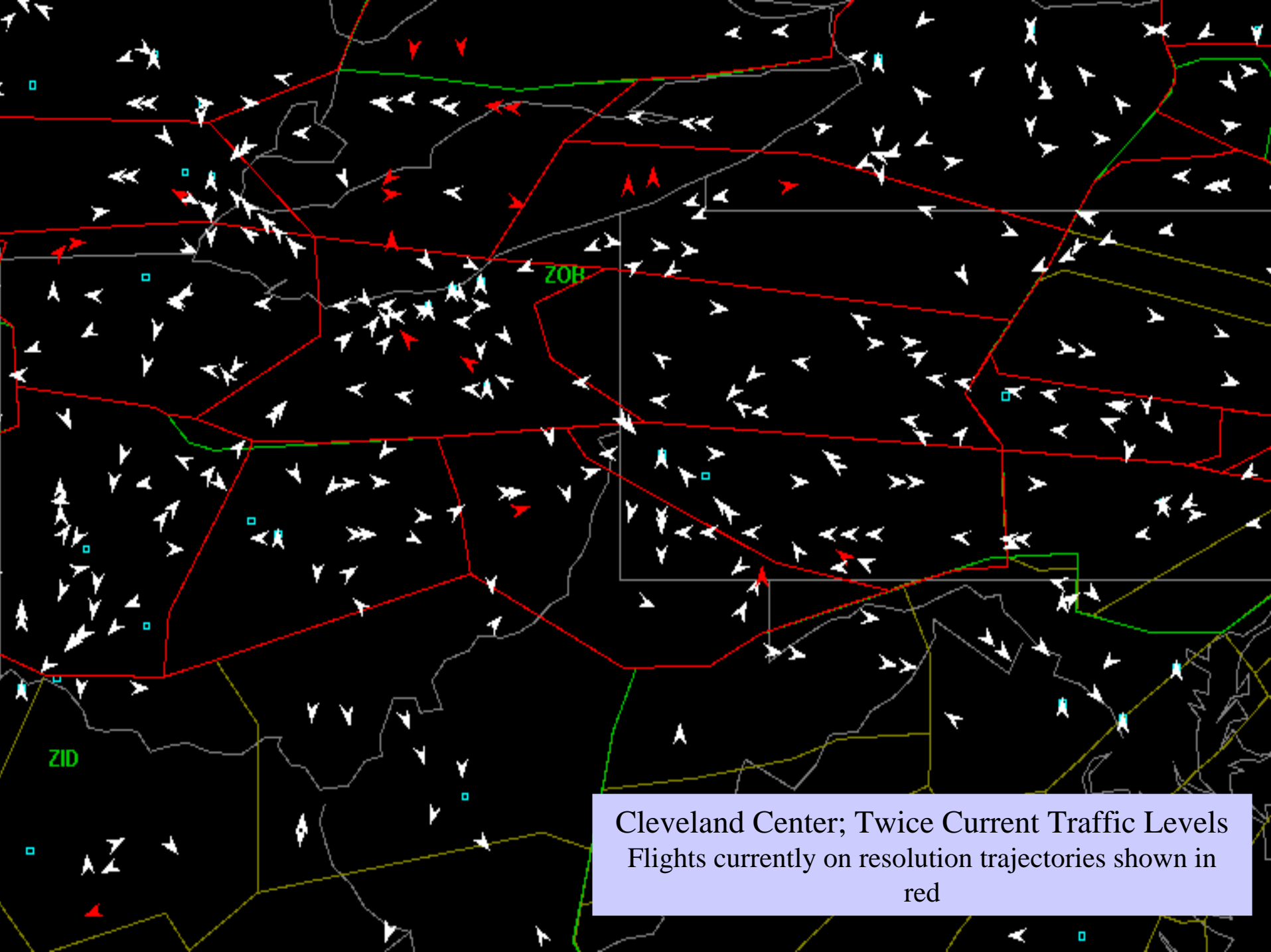


Performance of Resolution Generator

- Research software of algorithm has been implemented and is being evaluated using ACES
 - 24 hour traffic sample from Cleveland Center
 - Compare performance: Current density vs. 2 times current density
 - Conflict free time horizon: 12 min.; Min. time to first loss: 1 min.
 - Descent vs. descent conflicts in-tail to common feeder gate not included in resolution
 - Available trial plans: 40+
- Estimate capacity limit of algorithm by measuring:
 - Rise in the frequency of new conflicts during trial resolutions
 - # of trial plans required to clear new trial plan conflicts



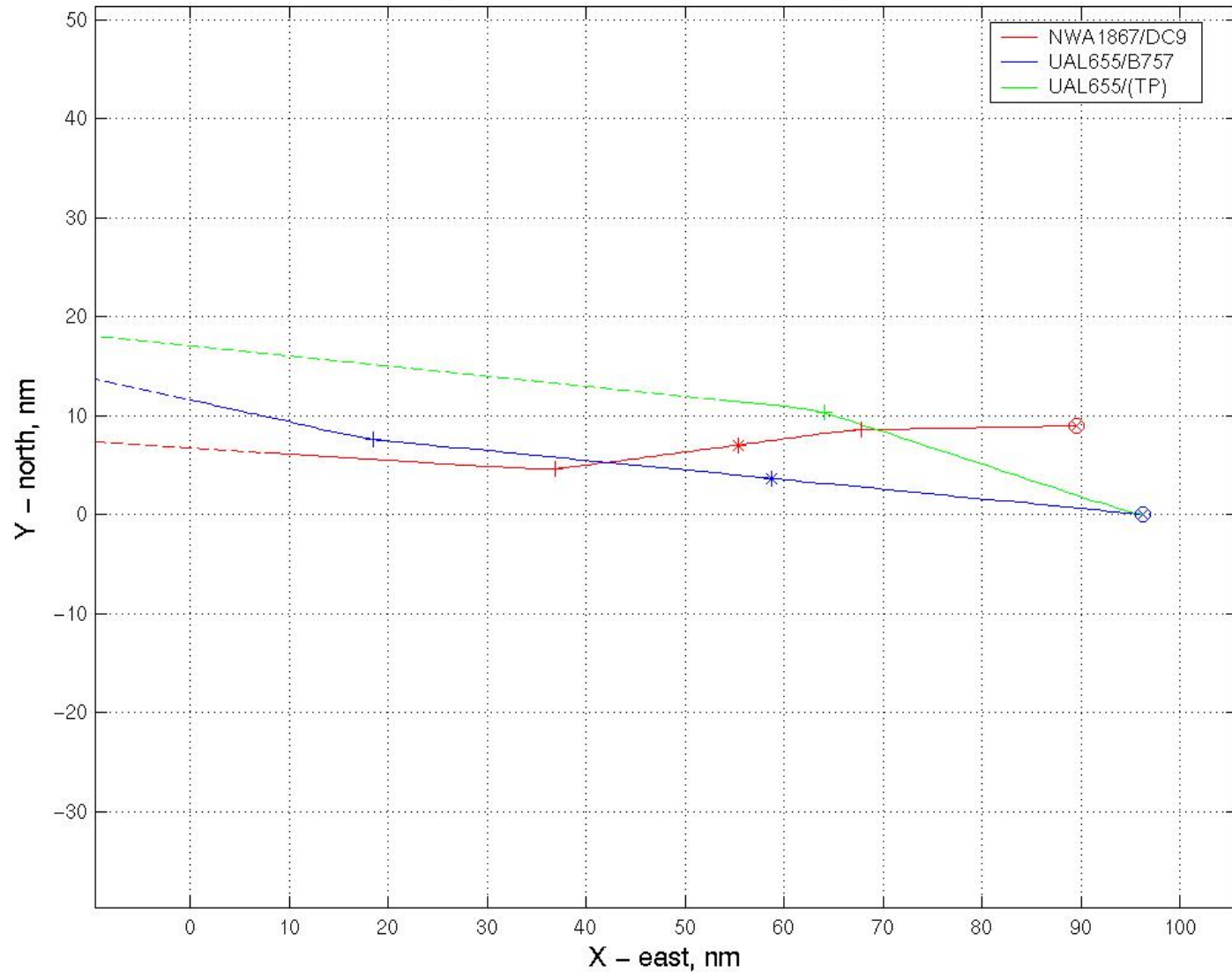
Cleveland Center; Current Traffic Levels
Flights currently on resolution trajectories shown in
red



Cleveland Center; Twice Current Traffic Levels
Flights currently on resolution trajectories shown in
red

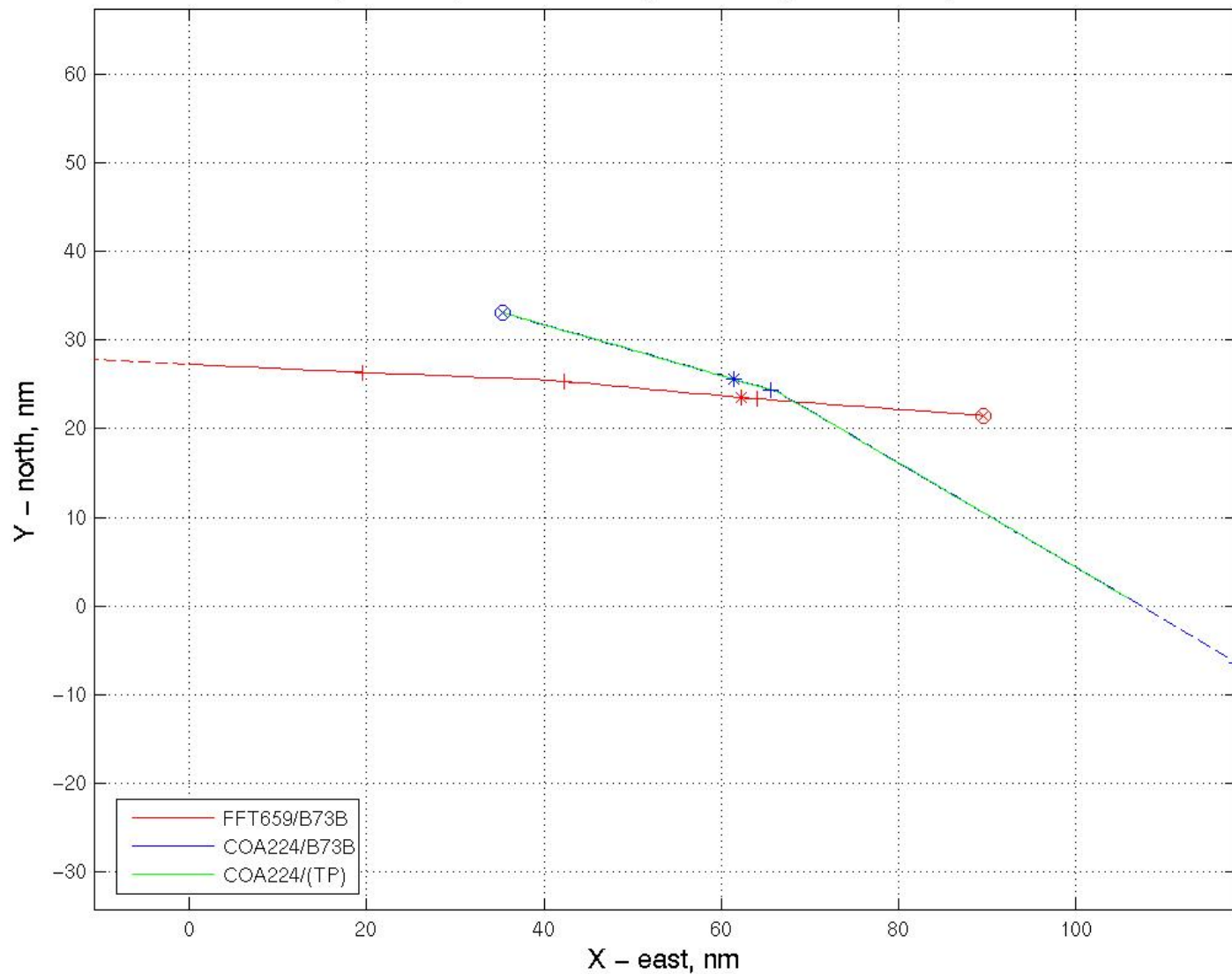
Resolution: Turn to Auxiliary Waypoint

File: NWA1867_UAL655_14:16:30_6ckf13; NWA1867: CR-CR; UAL655: CR-CR
tFL: 14:21:10; TP: Turn to aux wpt for UAL655; Res: Successful

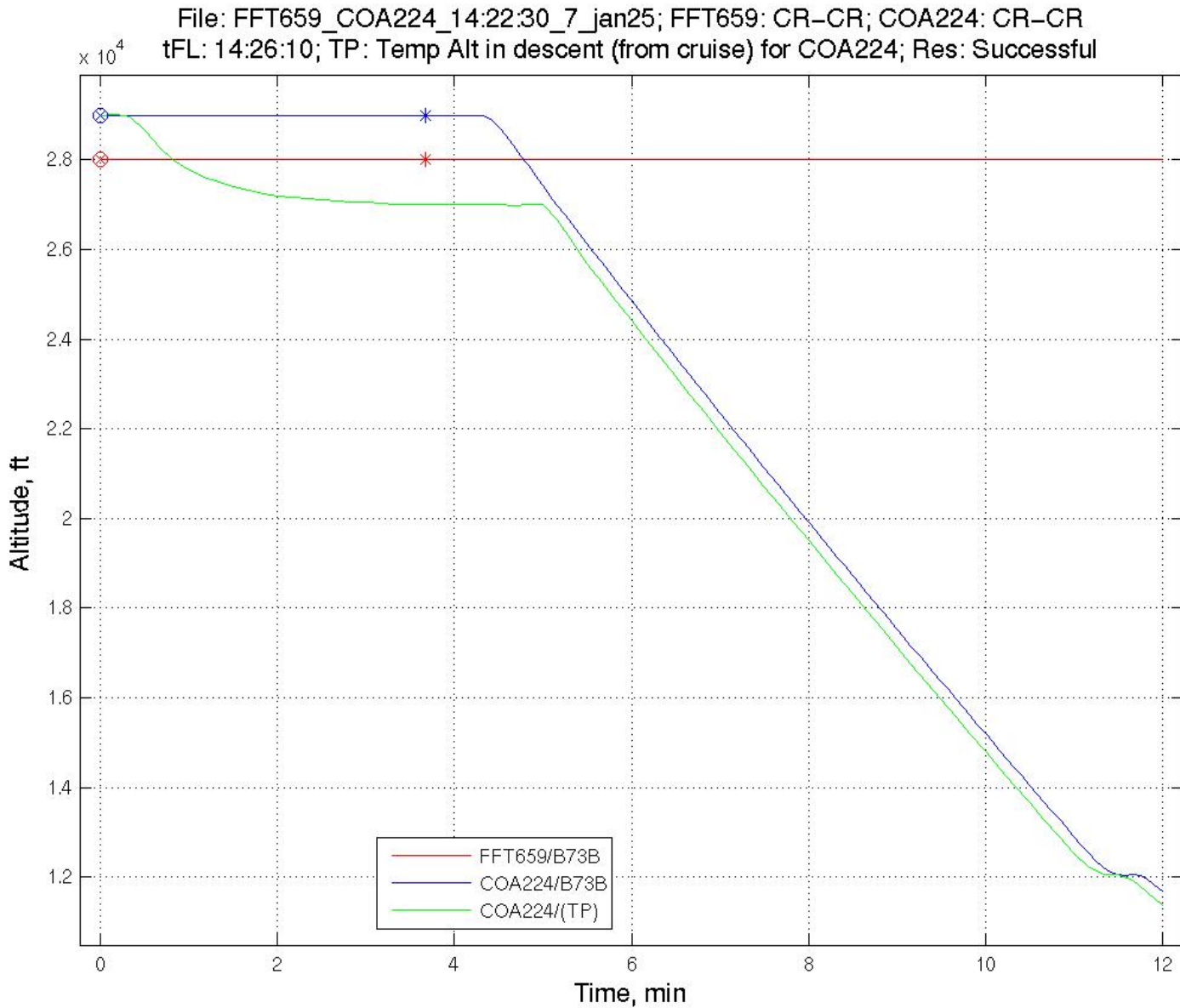


Trial Plans for Resolving the Same Conflict

File: FFT659_COA224_14:22:30_7_jan25; FFT659: CR-CR; COA224: CR-CR
tFL: 14:26:10; TP: Temp Alt in descent (from cruise) for COA224; Res: Successful



Temporary Altitude from Cruise (Successful)



Preliminary Results

Conflict Types, percent

Climb-Climb: 3 Climb-Descent: 3 Climb-Cruise: 28
Pure Cruise-Cruise: 38 Cruise-Descent: 23 Descent-Descent: 5

Types of Resolution Trajectories, percent

Vertical: 90 Horizontal: 9 Speed: 1

Trial Resolution Performance Statistics

Traffic sample	# of flights processed	Conflicts resolved	# of prim. conflicts with t.p. conflicts	# of t.p. to clear t.p. conflicts	# of T.P. per primary conflict
Current levels (5/17 set)	6400	424	90 (0.21*)	451	5.0
Twice current levels	12715	1530	408 (0.27*)	2546	6.2

* Ratio of # of primary conflicts with t.p. conflicts to total # of conflicts resolved

Conclusion

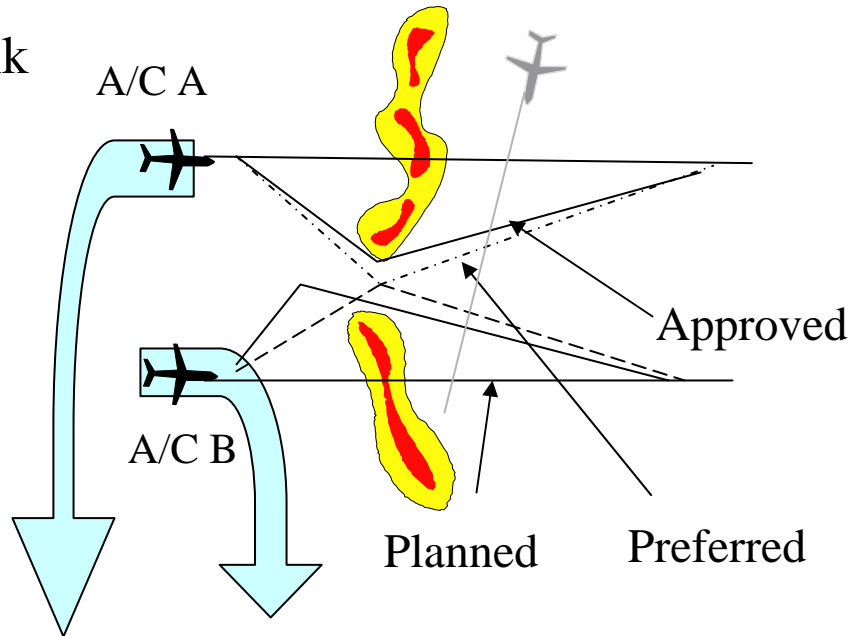
Resolution procedure can handle at least twice current traffic levels

Concept of Operations

- Pilots (or agents acting on behalf) of equipped aircraft choose trajectories and down link them to AAC ground system
- AAC ground system modifies requested trajectories if necessary to avoid conflicts and meet traffic management constraints; then uplinks approved trajectories
- AAC ground system checks periodically for conflicts and uplinks resolution trajectories to maintain separation
- Controller can assume manual control of selected aircraft at his/her discretion or if pilot requests special services
- AAC airspace controller designates self separation airspace to autonomous equipped aircraft when and where appropriate

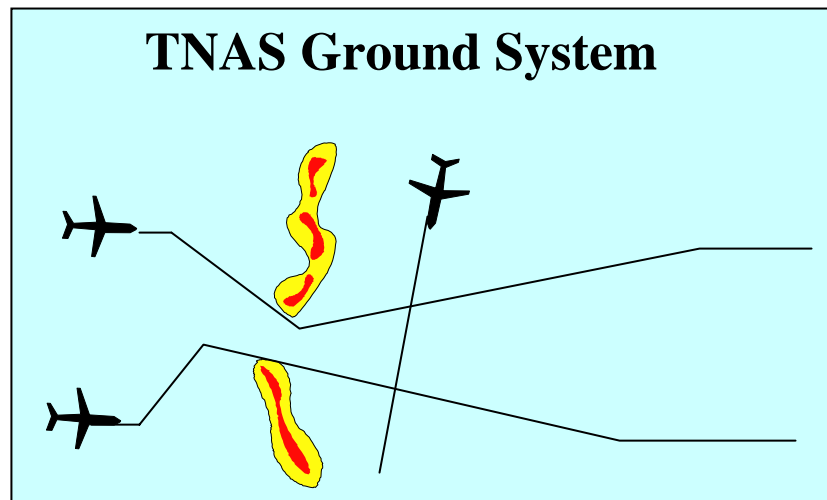
AAC En Route Operations

1. Pilots down link preferred trajectories



3. Pilots execute approved trajectories

2. Ground system eliminates conflicts and TFM violations, then uplinks approved trajectories



4. Ground system monitors tracking performance and uplinks resolution advisories if necessary

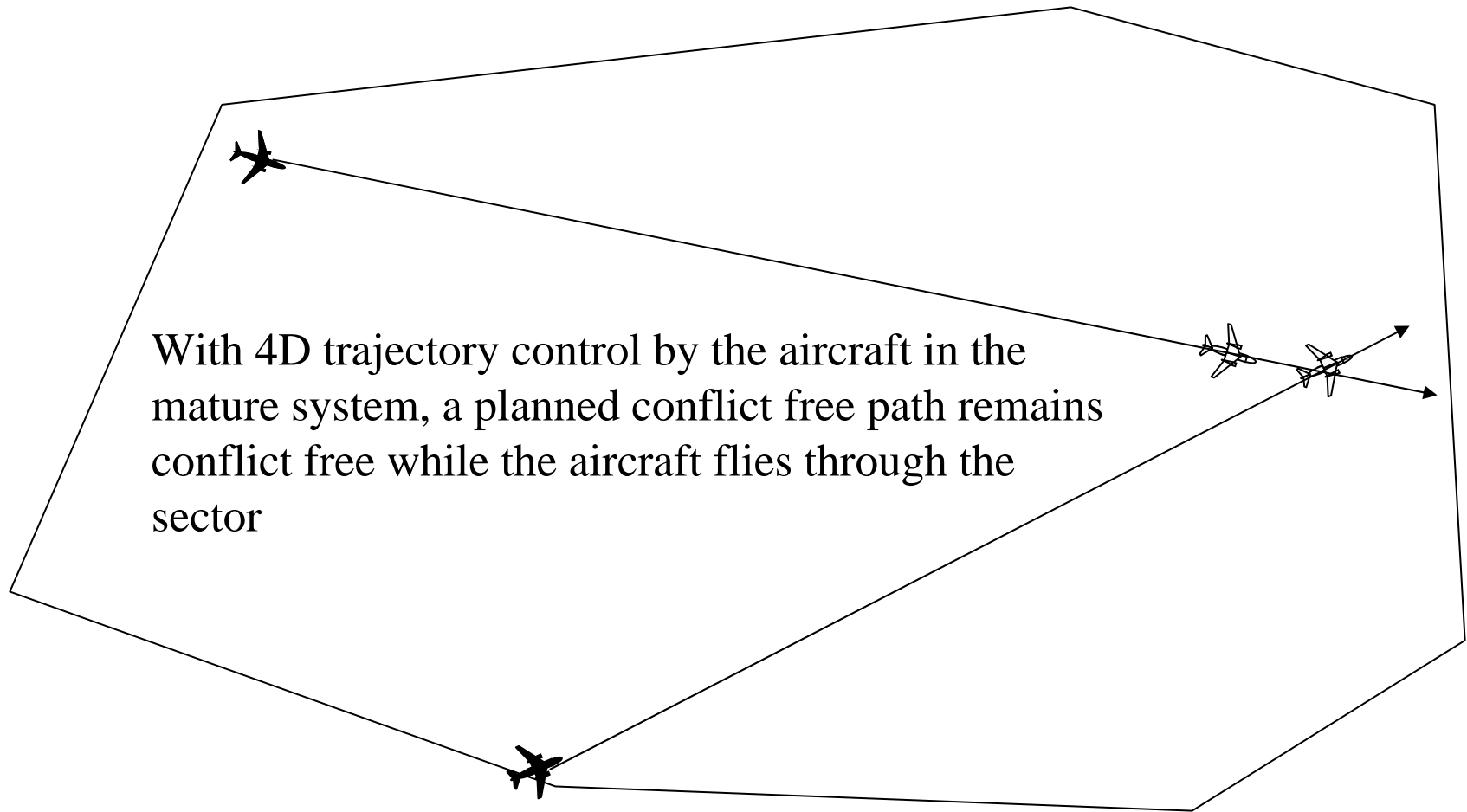
Safety Analysis

- A safety analysis has been conducted for AAC using fault tree methodology.
- Various types of faults were modeled, including AAC service interruptions.
- The analysis assumed traffic density of 3 times current max. density and an operations rate of 10 million flight hours per year in AAC airspace.
- Analysis of assumed faults indicates that a collision rate of less than 1 collision per 100 years is achievable with Concept
- A report on the study can be found in 42PM-AATT-0018, M.I.T. Lincoln Laboratory, June 2004.

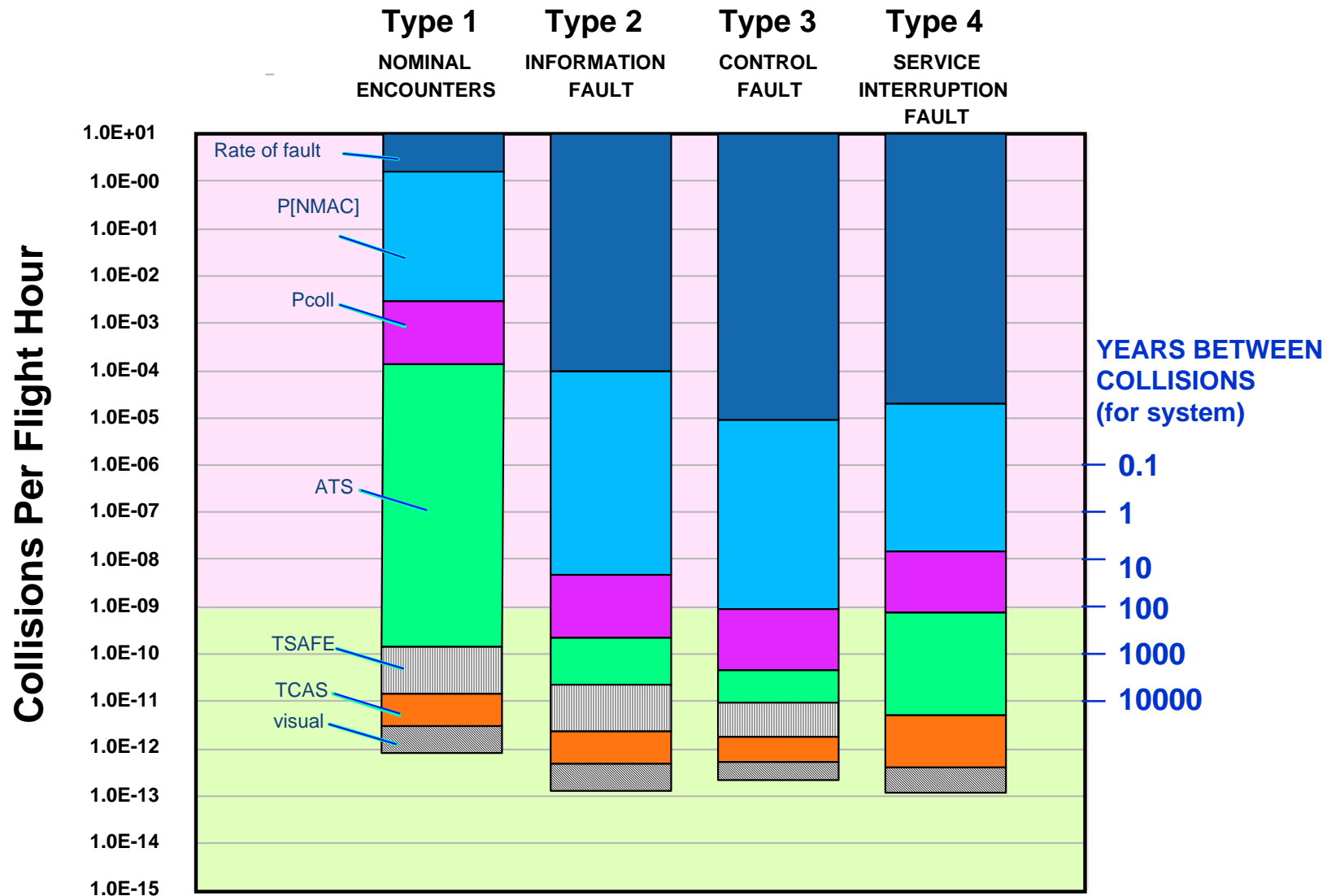
Types of Faults

<u>Fault Type</u>	<u>Fault Name</u>	<u>Description</u>
1	Nominal Encounter	Encounter between two aircraft in which no other defined faults are present.
2	Information Non-conformance	Aircraft deviates from trajectory due to faulty information or misunderstanding
3	Control Non-conformance	Aircraft deviates from trajectory due to control problem
4	Service interruption	Normal AAC service is halted for all aircraft in the AAC sector.

The role of 4D trajectories during AAC Service Failures



Risk Assessment for Faults



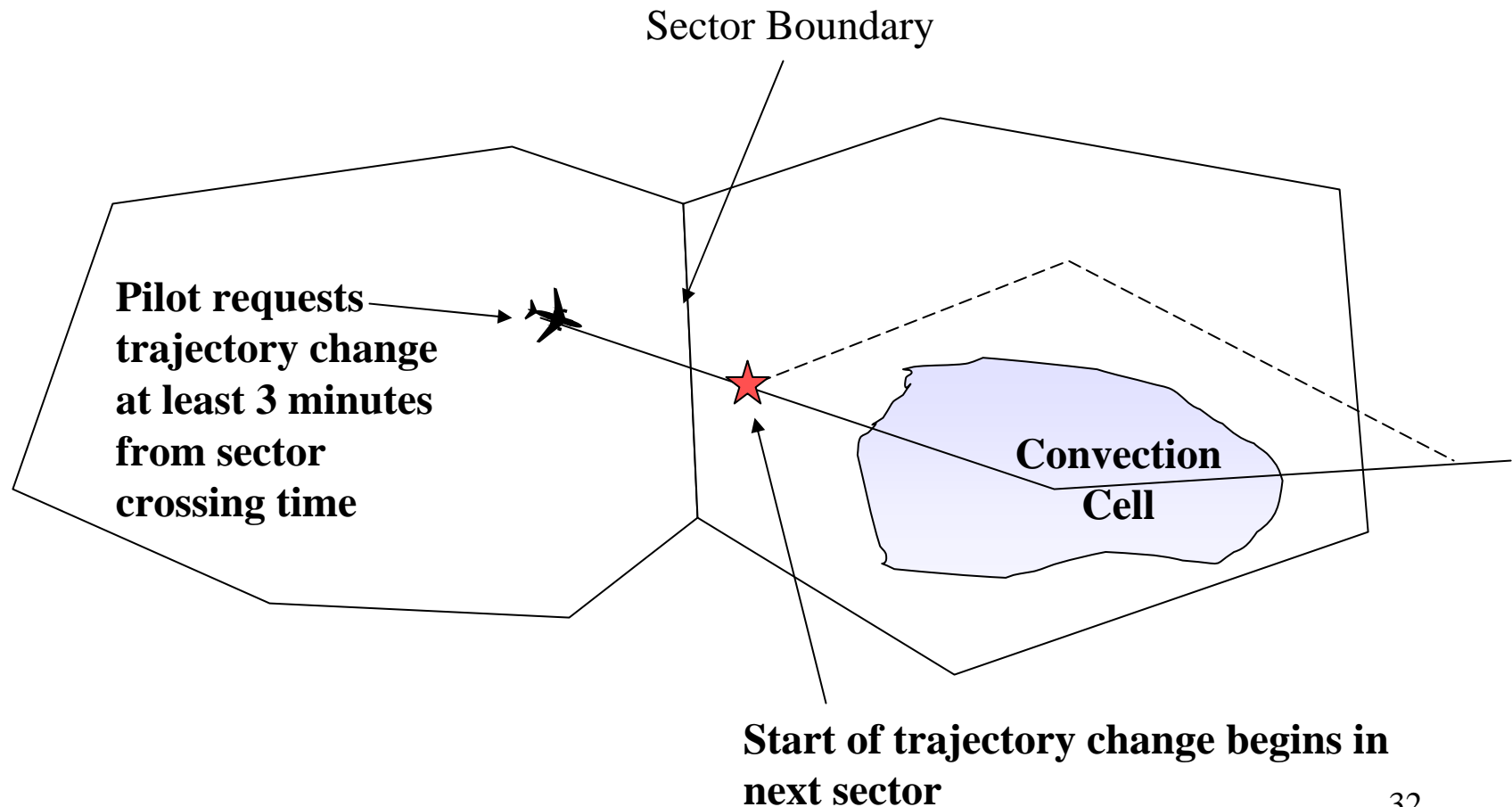
Note: Years between collision assumes 1.0E07 hours of exposure per year.

Procedures for Transitioning to Initial AAC Operations

- Sector controller team approves AAC generated trajectory changes before they are up-linked to aircraft
- Start of AAC trajectory changes delayed past controller's tactical control horizon (~5 minutes), giving controllers time to reject or revise
- Controller decides if/when to “hand off” an equipped aircraft to AAC and when to resume manual control
- Limited types of AAC trajectory clearances: for example, altitude amendments only or route amendments only
- Fully autonomous operations implemented for high altitude en route airspace

Initial Functionality for AAC:

Downlinked trajectory changes delayed to start in next Sector



Concluding Remarks

- AAC has potential to increase capacity substantially by reducing controller workload associated with tactical separation assurance
- Ground-based system provides automated trajectory services and separation assurance to aircraft via datalink
- CPDLC, VDL, Mode S up-link and ERAM provide the essential infrastructure for supporting AAC operations
- Cost of onboard equipage can be kept low
- Cockpit Display of Traffic Information using ADS-B can contribute to the safety net of AAC operations
- Resolution Generator and TSAFE are basic building blocks in design of autonomous airborne separation assurance concepts
- AAC operations could be introduced in evolutionary steps beginning in about 2014